CHAPTER 18

SOIL STABILIZATION

Soil stabilization may be broadly defined as the alteration or preservation of one or more soil properties to improve the engineering characteristics and performance of a soil. This chapter is intended to provide you with a brief overview of soil stabilization in terms of (1) stabilization methods, (2) the types and selection of various chemical stabilizers used in soil stabilization and (3) general guidance and information relative to the design and testing of soil-cement and soil-bituminous mixtures. For a thorough understanding of the subject of soil stabilization, you should combine the study of this chapter with the study of the various references cited within the chapter.

METHODS OF STABILIZATION

The two general methods of stabilization are mechanical and additive. The effectiveness of stabilization depends upon the ability to obtain uniformity in blending the various materials. Mixing in a stationary or traveling plant is preferred; however, other means of mixing, such as scarifies, plows, disks, graders, and rotary mixers, have been satisfactory.

The method of soil stabilization is determined by the amount of stabilizing required and the conditions encountered on the project. An accurate soil description and classification is essential to the selection of the correct materials and procedures. Table 18-1 lists the

Table 18-1.—Stabilization Methods Most Suitable for Specific Applications

Purpose	Soil type	Method
1. Subgrade stabilization a. Improved load carrying and stress distribution characteristics.	Fine granular	SA, SC, MB, C
	Coarse granular	SA, SC, MB, C
	Clays of low PI	C, SC, CMS, LMS, SL
	Clays of high PI	SL, LMS
b. Reduce frost susceptibility	Fine granular	CMS, SA, SC, LF
	Clays of low PI	CMS, SC, SL, LMS
c. Waterproofing and improved runoff	Clays of low PI	CMS, SA, LMS, SL
d. Control of shrinkage and swell	Clays of low PI	CMS, SC, C, LMS, SL
	Clays of high PI	SL
e. Reduce resiliency	Clays of high PI	SL, LMS
	Plastic silts or clays	SC, CMS
2. Base coarse stabilization a. Improvements of substandard materials	Fine granular	SC, SA, LF, MB
	Clays of low PI	SC, SL
b. Improved load carrying and stress distribution characteristics.	Coarse granular	SA, SC, MB, LF
	Fine granular	SC, SA, LF MB
c. Reduction of pumping	Fine granular	SC, SA, LF, MB, membranes
3. Dust palliative	Fine granular	CMS, SA, Oil or bituminous surface spray, APSB
	Plastic soils	CMS, SL, LMS, APSB, DCA 70

Where the methods of treatment are:
APSB = Asphalt Penetration Surface Binder
C = Compaction
CMS = Cement modified Soil
DCA70 = Polyvinylacetate emulsion
LF = Lime Fly ash
LMS = Lime Modified Soil
MB = Mechanical Blending
SA = Soil-Asphalt
SC = Soil-Cement
SL = Soil-Lime

most suitable treatments for various soil types to stabilize these soils for different objectives.

MECHANICAL METHOD

Mechanical stabilization is accomplished by mixing or blending soils of two or more gradations to obtain a material meeting the required specification. The soil blending may take place at the construction site, at a central plant, or at a borrow area. The blended material is then spread and compacted to required densities by conventional means.

ADDITIVE METHOD

Additive refers to a manufactured commercial product that, when added to the soil in the proper quantities, will improve the quality of the soil layer. This chapter is directed towards the use of portland cement, lime, lime-cement-fly ash, and bitumen, alone or in combination, as additives to stabilize soils. The selection and determination of the percentage of additives depend upon the soil classification and the degree of improvement in soil quality desired. Generally, smaller amounts of additives are required to alter soil properties, such as gradation, workability, and plasticity, than to improve the strength and durability sufficiently to permit a thickness reduction design. After the additive has been mixed with the soil, spreading and compacting are accomplished by conventional means.

Stabilization by Cementing Action

This method requires the addition of chemical agents to the soil to produce the hardened product. There are three main stabilizing agents that can be added, and the method of treatment bears the name of these agents: soil-cement, soil-lime, and lime-fly ash. The methods of chemical stabilization have much in common and involve somewhat similar construction practices. They depend upon hydration, pozzolanic action of lime with silica and alumina, alteration of the clay material, or a combination of these actions. The result is a semirigid, fairly brittle material with considerable compressive strength and moderate flexural strength when tested either statically or dynamicaly. The ultimate strength depends to a great degree on the density that is achieved during compaction and before the mix cures.

Bituminous Stabilization

In bituminous treatment, the end product performs differently—at least initially, and the product is much less brittle. Additionally, its behavior depends on the nature of the loading (static or dynamic) and the temperature when the load is applied.

MODIFICATION METHOD

Soil stabilization by modification usually results in something less than a thoroughly cemented, hardened or semihardened material. This type of stabilization may be accomplished by compacting, by mechanical blending, by adding cementing materials in small amounts, or by adding chemical modifiers. Cement and lime modifiers (cement-modified soil and lime-modified soil) are used in quantities too small to provide high-strength cementing action. They reduce the plasticity of clay soils. Calcium chloride or sodium chloride is added to the soil to retain moisture (and also control dust), to hold fine material for better compaction, and to reduce frost heave by lowering the freezing point of water in the soil. Bituminous materials, such as cutback asphalts or asphaltic penetrative soil binder (APSB), and certain chemicals, such as polyvinyl acetate emulsion (DCA-70), are used to waterproof the soil surface and to control dust.

GENERAL REQUIREMENTS FOR USE OF STABILIZERS

This section discusses different types of stabilizers. It also provides a method of selecting the type or types of stabilizers that you can use for various conditions. Before a proper stabilizer can be selected, however, you must first perform, or have performed, a sieve analysis and Atterberg limits tests for the particular type of soil you are concerned with. Both sieve analysis and Atterberg limits testing are discussed in the EA3 TRAMAN and in *Materials Testing,* NAVFAC MO-330.

LIME

Experience shows that lime will react with many medium, moderately fine, and fine-grained soils to produce decreased plasticity, increased workability, reduced swell, and increased strength. Soils classified according to the Unified Soil Classification System (USCS) as CH, CL, MH, ML, OH, OL, SC, SM, GC, GM, SW-SC, SP-SC, SM-SC, GW-GC, GP-GC, ML-CL, and GM-GC should be considered as potentially capable of being stabilized with lime.

CEMENT

Cement can be used as an effective stabilizer for a wide range of materials. In general, however, the soil should have a PI less than 30. For coarse-grained soils, the amount passing the No. 4 sieve should be greater than 45 percent.

Fly ash, when mixed with lime, can be used effectively to stabilize most coarse- and medium-grained soils. However, the PI should not be greater than 25. Soils classified by the USCS as SW, SP, SP-SC, SW-SC, SW-SM, GW, GP, GP-GC, GW-GC, GP-GM, GW-GM, GC-GM, and SC-SM can be stabilized with fly ash.

BITUMINOUS

Most bituminous soil stabilization has been performed with asphalt cement, cutback asphalt, and asphalt emulsions. Soils that can be stabilized effictively with bituminous materials usually contain less than 30 percent passing the No. 200 sieve and have a PI less then 10. Soils classified by the USCS as SW, SP, SW-SM, SP-SM, SW-SC, SP-SC, SM, SC, SM-SC, GW, GP, SW-GM, SP-GM, SW-GC, GP-GC, GM, GC, and GM-GC can be effectively stabilized with bituminous materials provided the above-mentioned gradation and plasticity requirements are met.

Combination stabilization is specifically defined as lime-cement, lime-asphalt, and lime-cement-fly ash (LCF) stabilization. Combinations of lime and cement often are acceptable expedient stabilizers. Lime can be added to the soil to increase the workability and mixing characteristics of the soil as well as reduce its plasticity. Cement can then be mixed into the soil to provide rapid strength gain. Combinations of lime and asphalt are often acceptable stabilizers. The lime addition may prevent stripping at the asphalt-aggregate interface and increase the stability of the mixture.

SELECTION OF A STABILIZER

In the selection of a stabilizer additive, the factors that must be considered are the type of soil to be stabilized, the purpose for which the stabilized layer will be used, the type of soil quality improvement desired, the required strength and durability of the stabilized layer, and the cost and environmental conditions.

The soil gradation triangle in figure 18-1 is based upon the pulverization characteristics of the soil. When

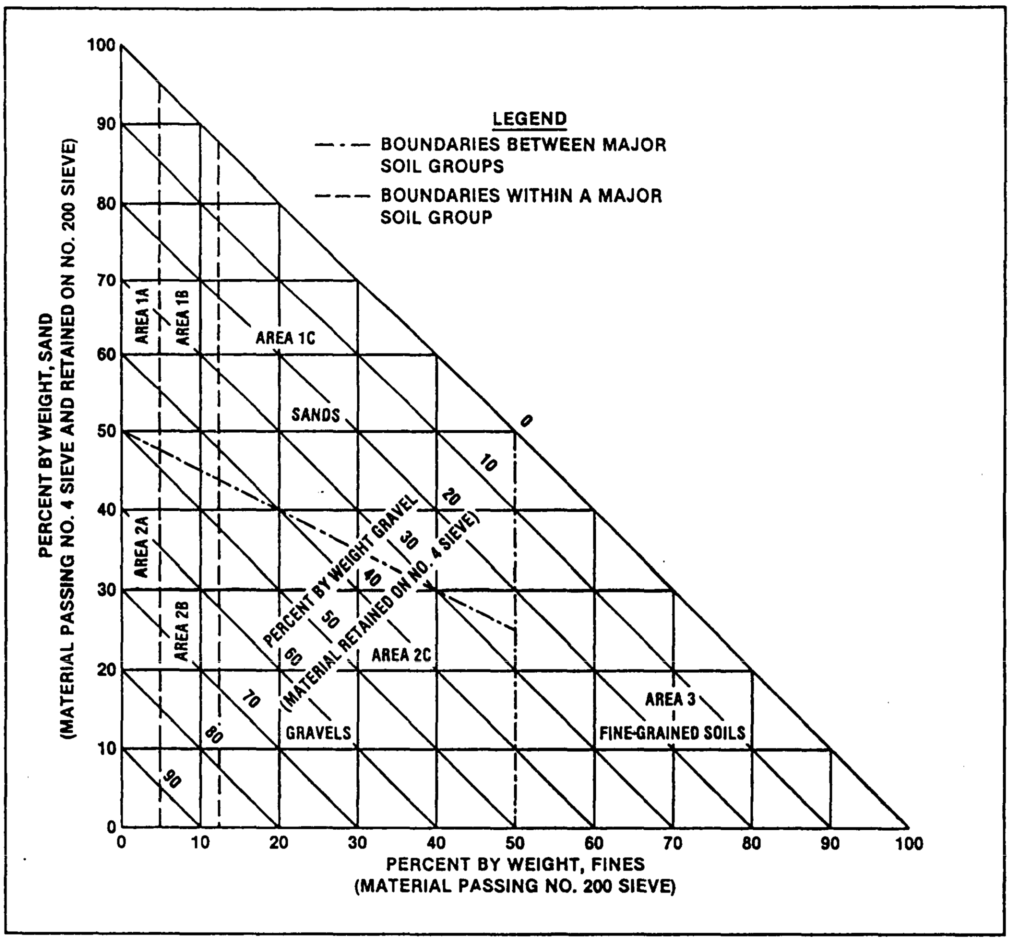

Figure 18-1.—Soil gradation triangle.

Table 18-2.—Guide for Selecting a Stabilizing Additive

Area	Soils class [1]	Type of stabilizing additive recommended	Restriction on LL and PI of soil	Restriction on percent passing No. 200 sieve[1]	Remarks
1A	SW or SP	Bituminous Portland cement Lime-cement-fly ash	 PI not to exceed 25		
1B	SW-SH or SP-SH or SW-SC or	Bituminous Portland cement Lime	PI not to exceed 10 PI not to exceed 30 PI not less than 12		
1C	SM or SC or SM-SC	Bituminous Portland cement Lime Lime-cement-fly ash	PI not to exceed 10 See footnote 2 PI not less than 12 PI not to exceed 25	Not to exceed 30% by weight	
2A	GW or GP	Bituminous Portland cement Lime-cement-fly ash	 PI not to exceed 25		Well-graded material only Material should contain at least 45% by weight of material passing No. 4 sieve
2B	GW-GH or GP-GH or GW-GC or GP-GC	Bituminous Portland cement Lime Lime-cement-fly ash	PI not to exceed 10 PI not to exceed 30 PI not less than 12 PI not to exceed 25		Well-graded material only Material should contain at least 45% by weight of material passing No. 4 sieve
2C	GM or GC or GM-GC	Bituminous Lime Lime-cement-fly ash	PI not to exceed 10 See footnote 2 PI not less than 12 PI not to exceed 25	Not to exceed 30% by weight	Well-graded material only Material should contain at least 45% by weight of material passing No. 4 sieve
3	CH or CL or HII or ML or OII or OL or ML-CL	Portland cement Lime	LL less than 40 and PI less than 20 PI not less than 12		Organic and strongly acid soils falling within this area are not susceptible to stabilization by ordinary means

[1] Soil classification corresponds to MIL-STD-619B. Restriction on liquid limit (LL) and plasticity index (PI) is in accordance with Method 103 in MIL-STD-621A.

[2] $PI \leq 20 + \frac{50 - \text{percent passing No. 200 sieve}}{4}$

these characteristics are combined with certain restrictions relative to liquid limit (LL) and soil gradation contained in table 18-2, they provide guidance for the selection of the additive best suited for stabilization. Figure 18-1 is entered with the percentage of gravel (percent material retained on the No. 4 sieve), sand (percent material passing the No. 4 sieve and retained on the No. 200 sieve), and fines (percent material passing the No. 200 sieve) to determine the area in which the soil gradation falls. The areas (1A, 2C, and 3) indicated at the intersection of the three material percentages are used to enter table 18-2 to select the type of stabilizing additive based on the various restrictions and remarks. For example, a soil having a PI of 15 and 57-percent gravel, 26-percent sand and 7-percent fines fall in area 2B of figure 18-1. Table 18-2 indicates that cement, lime, LCF, or bitumen could be considered. However, the PI of 15 eliminates bitumen, and the fact that only 33 percent of the material passes the No. 4

sieve indicates that lime or a combination LCF will be the best additive for Stabilization

SOIL-CEMENT STABILIZATION

In general, there are three types of soil-and-cement mixtures as follows:

- **Plastic soil-cement** is a hardened mixture of soil and cement that contains, at the time of placing, enough water to produce a consistency similar to plastering mortar. It is used to line or pave ditches, slopes, and other areas that are subject to erosion. It also maybe used for emergency road repair by mixing high-early-strength cement into the natural material in mudholes.

- **Cement-modified soil** is an unhardened or semihardened mixture of soil and cement. When relatively small quantities of portland cement are added to granular soil or silt-clay soil, the chemical and physical properties of that soil are changed. Cement reduces the plasticity and water-holding capacity of the soil and increases its bearing value. The degree of improvement depends upon the quantity of the cement used and the type of soil. In cement-modified soil, only enough cement is used to change the physical properties of the soil to the degree desired. Cement-modified soils may be used for base courses, subbases, treated subgrades, highway fills, and as trench backfill material.

- Compacted soil-cement, often referred to as simply soil-cement, is a mixture of pulverized soil and calculated amounts of portland cement and water that is compacted to a high density. The result is a rigid slab having moderate compressive strength and resistance to the disintegrating effects of wetting and drying and freezing and thawing. The remainder of our discussion of soil-cement is directed towards this type of soil-and-cement mixture.

MATERIALS FOR SOIL-CEMENT

Soil, portland cement, and water are the three basic materials needed to produce soil-cement. Low cost is achieved mainly by using inexpensive local materials. The soil that makes up the bulk of soil-cement is either in place or obtained nearby, and the water is usually hauled only short distances.

The word *soil, as* used in soil-cement, means almost any combination of gravel, sand, silt, and clay, and includes such materials as cinder, caliche, shale, laterite, and many waste materials including dirty and poorly graded sands from gravel pits.

The quantities of Portland cement and water to be added and the density to which the mixture must be compacted are determined from tests. The water serves two purposes: it helps to obtain maximum compaction (density) by lubricating the soil grains and it is necessary for hydration of the cement that hardens and binds the soil into a solid mass. Properly produced soil-cement contains enough water for both purposes.

The cement could be almost any type of portland cement that complies with the requirements of the latest ASTM (American Safety for testing and Materials), AASHTO(American Association of State Highway and Transportation Officials), or federal specifications. Types I (normal) and IA (air entrained) portland cements are the most commonly used.

The water used in soil-cement should be relatively clean and free from harmful amounts of alkalies, acid, or organic matter. Water fit to drink is satisfactory. Sometimes seawater has been used satisfactorily when fresh water has been unobtainable.

Practically all soils and soil combinations can be hardened with portland cement. They do not need to be well-graded aggregates since stability is attained primarily through hydration of cement and not by cohesion and internal friction of the materials. The general suitability of soils for soil-cement can be judged before they are tested on the basis of their gradation and their position in the soil profile. On the basis of gradation, soils for soil-cement construction can be divided into three broad groups as follows:

1. Sandy and gravelly soils with about 10- to 35-percent silt and clay combined have the most favorable characteristics and generally require the least amount of cement for adequate hardening. Glacial-and water-deposited sands and gravels, crusher-run limestone, caliche, lime rock and almost all granular materials work well if they contain 55 percent or more material passing the No. 4 sieve and 37 percent passing the No. 10 sieve. Stones over an inch or two in diameter are undesirable. Exceptionally well-graded materials may contain up to 65-percent gravel retained on the No. 4 sieve and have sufficient fine material for adequate binding. These soils are readily pulverized, easily mixed and can be used under a wide range of weather conditions.

2 Sandy soils deficient in fines, such as some beach sands, glacial sands, and windblown sands, make good soil-cement although the amount of cement needed for adequate hardening is usually slightly greater than with the soil in Group 1 above. Because of poor

gradation and absence of fines in these sands, construction equipment may have difficulty in obtaining traction. Traction can be vastly improved by keeping the sand wet and by using track-type equipment. These soils are likely to be "tender" and to require care during final packing and finishing so that a smooth, dense surface may be obtained.

3. Silty and clayey soils make satisfactory soil-cement but those containing high clay contents are harder to pulverize. Generally the more clayey the soil, the higher the cement content required to harden it adequately. Construction with these soils is more dependent on weather conditions. If the soil can be pulverized it is not too heavy textured for use in soil-cement.

SOIL-CEMENT TESTS

Laboratory tests determine three fundamental control factors for soil-cement. These factors are as follows:

1. Proper cement content
2. Proper moisture content
3. Roper density

An adequate cement content is the first requisite for quality soil-cement. Well before construction, the soils at a project site should be identified, the limits of each soil defined, and a representative sample of each soil type should be forwarded to the laboratory to determine the quantity of cement required to harden it. A soil survey of the construction area should be made.

Proper soil surveying, identification, and sampling are important. For instance, if one soil type was sampled and tested while actual construction involved a different soil type, the tests would be worthless and, in fact, detrimental since they would mislead the engineers. Obviously, it is important to sample and test the soils that will actually be used in soil-cement construction. A 75-pound sample of each type of soil is adequate for laboratory testing.

Sampling methods and procedures are discussed in the EA3 TRAMAN and in NAVFAC MO-330. Soil samples are usually taken from a graded roadway by digging a trench from the center line to the edge of the proposed pavement and to the depth of processing. Soil samples for proposed roadways not yet graded are taken with an auger from the various soil horizons of each soil type from the "dressed-down" face of exposed cuts or from the surface. Samples should be taken so that only one horizon of each soil type is represented by each sample. Similarly, it is not good practice to take a composite sample from various locations. Data obtained from a composite sample does not apply to soil in any single location and may be misleading. There are exceptions. For instance, in sampling pit material that is to be loaded during construction by a shovel operating over the vertical face of the pit, the sample is taken from the bottom to the top of the vertical face after the overburden is removed. On small projects, it is not uncommon to sample only the poorest soil on the job, and the cement content for this sample is used throughout the job. Be sure that complete identification is supplied with each sample.

The purpose of laboratory testing is to determine the minimum cement content needed to harden the material adequately and the optimum moisture content (OMC) and density values to be used for construction. The OMC and maximum density are determined by the **moisture-density test** and the required cement content is determined by either the **wet-dry test** for pavements located in nonfrost areas or the **freeze-thaw test** for pavements located in frost areas. A brief description of each test is provided below.

- The **moisture-density test** determines the OMC and maximum density for molding laboratory specimens and, in the field, to determine the quantity of water to be added and the density to which the soil-cement mixture should be compacted.

Before you start this test, select the cement contents that will be used in the wet-dry or freeze-thaw test. The cement contents are usually selected in 2-percent increments to encompass values given in table 18-3.

Table 18-3.—Basic Range of Cement Requirements

Soil classification*	Cement required (percent by weight)
GW, GP, SW, SP, GM, or SM . . .	3-5
SP, GM, SM, or GP	5-8
SM, SC, some GM, or GC	5-9
SP	7-11
CL or ML	7-12
ML, MH, or OH	8-13
CL or CH	9-15
OH, MH, or some CH	10-16

* See appendix V for soil classifications

Since maximum density varies only slightly with variations in the cement content, only the median value is used in preparing specimens for the test. Additional information on selecting the cement content can be found in chapter 5 of NAVFAC MO-330.

The procedures for determining the OMC are similar to those described in chapter 13 of this TRAMAN with the following exceptions:

1. Compaction is performed on five layers of approximately equal thickness to result in a total compacted depth of 5 inches.

2. Each layer is compacted by 25 uniformly spaced blows using a 10-pound tamper dropped from a height of 18 inches.

- The **wet-dry test** (ASTM D 559) determines the cement content for soil-cement mixtures used in nonfrost areas. The objective is to determine the minimum amount of cement that will enable the soil-cement mixture to pass the test. For the test, specimens are molded using the OMC and the cement contents described above for different soil classifications. Use the procedure for the OMC determination to mold the specimens, and take a 750-gram sample from the second layer for a moisture determination. Cure the specimens for 7 days in high humidity. After curing, the specimens are weighed and submerged in tap water at room temperature for 5 hours. They are then oven-dried for 42 hours at 160°F. Material loosened by wetting and drying is then removed using two firm strokes of a wire brush. After this, you then reweigh the specimens and subtract the new weight from the old weight to determine the amount of disintegration (soil-cement loss) that occurred during the cycle. The process is repeated for a total of 12 cycles. A passing grade ranges from 14-percent loss for sandy or gravelly soils down to 7 percent for clayey soil.

Additional information about the wet-dry test and an example of determining the soil-cement loss can be found in NAVFAC MO-330.

- The **freeze-thaw test** (ASTM D 560) determines the cement content for soil-cement mixtures used in areas subject to frost action due to repeated freezing and thawing. As in the wet-dry test, the objective of the freeze-thaw test is to determine the minimum amount of cement that enables the mixture to pass the test. For the test, specimens are molded and cured in the same manner as the wet-dry test. After 7 days of curing, the specimens are placed on moist blotters and are refrigerated for 24 hours at -10°F. They are then thawed in a moist atmosphere at 70°F for 23 hours. Then you brush the specimens as described above and, if necessary, remove any half-loose scales using a sharp-pointed instrument. After 12 cycles, the specimens are oven-dried and weighed. The soil-cement loss is determined the same way as in the wet-dry test. Again, passing grades range from 14-percent loss for sandy or gravelly soils down to 7 percent for clayey soil.

For additional information regarding the freeze-thaw test, you should refer to NAVFAC MO-330.

The principal requirement of a hardened soil-cement mixture is to withstand exposure to the elements. Strength is a requirement also; however, most soil-cement mixtures that have adequate resistance to the elements also have adequate strength. In the ranges of cement contents producing results meeting the requirements above, the strength of soil-cement specimens tested in compression at various ages should increase with age and with increases in cement. A sample that has an unconfined compressive strength of approximately 300 pounds per square inch (psi) after curing 7 days and shows increasing strength with age can be considered adequately stabilized. NAVFAC MO-330 has the procedures that you should follow when performing unconfined compression tests.

For a discussion of modified mix design for sandy soils and for approximate and rapid test procedures that you can use when complete testing is impracticable, you should refer to NAVFAC MO-330. Construction methods using soil-cement can be found in *Military, Soils Engineering,* FM5-541, and in commercial publications, such as *Moving the Earth,* by Herbert L. Nichols, Jr., and various publications from the Portland Cement Association.

BITUMINOUS STABILIZATION

Bituminous soil stabilization refers to a process by which a controlled amount of bituminous material is thoroughly mixed with an existing soil or aggregate material to form a stable base or wearing surface. Bitumen increases the cohesion and load-bearing capacity of the soil and renders it resistant to the action of water.

SOIL GRADATION

The recommended soil gradations for subgrade and base or subbase course materials are shown in

Table 18-4.—Recommended Gradations for Bituminous-Stabilized Subgrade Materials

Sieve size	Percent passing
3 inch	100
No. 4	50 - 100
No. 30	38 - 100
No. 200	2 - 30

tables 18-4 and 18-5, respectively. Mechanical stabilization may be required to bring the soil to proper gradation.

TYPES OF BITUMEN

Bituminous stabilization is generally accomplished using asphalt cement, cutback asphalt, or asphalt emulsion. The type of bitumen to be used depends upon the type of soil to be stabilized, method of construction, and weather conditions.

In frost areas, the use of tar as a binder should be avoided because of its high-temperature susceptibility. Asphalts are affected less by temperature changes, but a grade of asphalt suitable to the prevailing climate should be selected. As a general rule, the most satisfactory results are obtained using the most viscous liquid asphalt that can be readily mixed into the soil. For higher quality mixes in which a central plant is used, viscosity-grade asphalt cements should be used.

Most bituminous stabilization is performed in place. The bitumen is applied directly on the soil or soil-aggregate system, and the mixing and compaction operations are conducted immediately thereafter. For this type of construction, liquid asphalts, such as cutbacks and emulsions, are used. Emulsions are preferred over cutbacks because of energy constraints and pollution control efforts.

The specific type and grade of bitumen will depend on the characteristics of the aggregate, type of construction equipment, and climate conditions. Generally, the types of bituminous materials that will be used for the soil gradation are indicated in table 18-6.

MIX DESIGN AND METHODS OF TESTING MIXTURES

For guidance on the design of bituminous-stabilized base and subbase courses, you should refer to *Bituminous Pavements—Standard Practice,* TM5-822-8, and to NAVFAC MO-330.

The *Tentative Method of Testing Soil-Bituminous Mixtures,* ASTM D 915, provides for determination of water absorption, expansion, and extrusion characteristics of compacted soil or soil-aggregate mixtures. The method maybe used for determining the characteristics of a mixture of specified proportions under specified conditions of curing or noncuring. Also, it may be used for determining the effects on these characteristics of varying the curing and the proportions of the different ingredients. The test results are not intended to determine thickness or to predict relative field performance of the different bituminous materials.

Table 18-5.—Recommended Gradations for Bituminous-Stabilized Subbase Materials

Sieve size	1 1/2-in. Maximum	1-in. Maximum	3/4-in. Maximum	1/2-in. Maximum
1 1/2 in.	100	----	----	----
1 in.	84 ±9	100	----	----
3/4 in.	76 ±9	83 ±9	100	----
1/2 in.	66 ±9	73 ±9	82 ±9	100
3/8 in.	59 ±9	64 ±9	72 ±9	83 ±9
No. 4	45 ±9	48 ±9	54 ±9	62 ±9
No. 8	35 ±9	37 ±9	41 ±9	47 ±9
No. 16	27 ±9	28 ±9	32 ±9	36 ±9
No. 30	20 ±9	21 ±9	24 ±9	28 ±9
No. 50	14 ±7	16 ±7	17 ±7	20 ±7
No. 100	9 ±5	11 ±5	12 ±5	14 ±5
No. 200	5 ±2	5 ±2	5 ±2	5 ±2

Table 18-6.—Bituminous Requirements

Open-graded aggregate Rapid- and medium-curing liquid asphalts RC-250, RC-800, and MC-3000 Medium-setting asphalt emulsion MS-2 and CMS-2
Well-graded aggregate with little or no material passing the No. 200 sieve Rapid- and medium-curing liquid asphalts RC-250, RC-800, MC-250, and MC-800 Slow-curing liquid asphalts SC-250 and SC-800 Medium-setting and slow-setting asphalt emulsions MS-2, CMS-2, SS-1, and CSS-1
Aggregate with a considerable percentage of fine aggregate and material passing the No. 200 sieve Medium-curing liquid asphalts MC-250 and MC-800 Slow-curing liquid asphalts SC-250 and SC-800 Slow-setting asphalt emulsions SS-1, SS-1h, CSS-1, and CSS-1h Medium-setting asphalt emulsions MS-2 and CMS-2
The simplest type of bituminous stabilization is the application of liquid asphalt to the surface of an unbound aggregate road. For this type of operation, the slow- and medium-curing liquid asphalts SC-70, SC-250, MC-70, and MC-250 are used.

QUESTIONS

Q1. *What type or types of additive(s) is/are best to use for stabilizing a soil that has a PI of 30 and contains 40-percent gravel 45-percent sand, and 15-percent fines?*

Q2. *For a soil-cement mixture, what type of soil is likely to require the highest cement content?*

Q3. *Assume that you are tasked with determining the cement content needed for a soil-cement mixture that will be used for a project located at a Marine Corps camp in South Korea. At a minimum, what laboratory tests will you need to perform?*

Q4. *You are preparing to do an unconfined compression test on a soil-cement mixture using a soil that is 40-percent gravel. What compaction mold should you use?*